Reforming Diesel Fuel to Hydrogen

The INL is participating in an Office of Naval Research/SOFCo-EFS program to design, build and test the world's largest first-generation integrated fuel processor that converts high-sulfur NATO-76 diesel fuel into hydrogen-rich gas for use in a fuel cell system. The 500 kW Integrated Fuel Processor Program, part of the Ship Service Fuel Cell Program of the U.S. Navy, could lead to technology that delivers innovative energy solutions – from clean electric power on Navy ships and luxury cruise liners to stand-alone power systems for remote areas such as rural Alaska.

This 500 kWe integrated fuel processor is the world's largest first-generation reformer that converts high-sulfur NATO-76 diesel fuel into hydrogen-rich gas for use in a fuel cell system.

How the Process Works

INL's integrated fuel processor produces gas for a fuel cell in essentially two steps: reforming the diesel fuel into a hydrogen-rich gas stream, and then cleaning the gas of impurities that could damage fuel cells. In this demonstration system, the hydrogen gas is fed in a third step to a catalytic burner, which simulates the Proton Exchange Membrane (PEM) fuel cell that would be implemented in fully-realized systems.

Step One: Fuel Reformation

The first piece of equipment, called the autothermal reformer, uses steam to vaporize incoming high-sulfur diesel fuel. This diesel vapor is then heated further and injected into a chemical-reaction bed, where it is carefully mixed with air and converted into a carbon monoxide-rich gas stream containing about 40 percent hydrogen by volume.

This reformed gas still contains a significant amount of sulfur, which must be removed to prevent poisoning of sensitive equipment further downstream. To do this, absorbent pellets act as a regenerating chemical sponge to draw sulfur from the gas stream. The gas then flows through a refining bed of zinc oxide to capture any residual amounts of sulfur.

Step Two: Gas Cleaning

Carbon monoxide in the gas stream can damage fuel cells and so must also be removed. The fuel processor does this in three stages, each of which produces increasingly cleaner hydrogen gas. In the first two stages, equipment called water-gas shift reactors mix the hydrogen gas stream with water. This produces a gas stream richer in hydrogen and also converts the carbon monoxide into harmless carbon dioxide. In the third stage, a process known as selective oxidation removes residual amounts of carbon monoxide. The cleaned gas stream now contains about 45 percent hydrogen by volume.

Step Three: Fuel Cell Simulation

Finally, the demonstration system uses a simulated fuel cell to verify the usability of the hydrogen gas produced in the first two steps. A catalytic burner combines about 80 percent of the hydrogen with added air to make heat and water, simulating a fuel cell that has about an 80 percent conversion rate. The gas composition is then similar to that

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of the exhaust from a genuine PEM fuel cell system. A second catalytic burner combines the rest of the hydrogen with yet more air to convert all the hydrogen to steam. The system then releases into the atmosphere a nonflammable mixture of carbon dioxide, steam and nitrogen.

Other Features

Safety and efficiency are built into the system. A process control computer tracks about 150 measurements – 50 of which can trip an automatic shutdown in two to five seconds. Heat produced in the first two steps is recovered and used to create steam and to bring the gas stream to optimal temperatures throughout the process. And the sulfur-absorbing pellets in the first step are recyclable: while a fresh bed of pellets is removing sulfur from the gas stream, trapped impurities in the first bed are converted to sulfur dioxide and released into the atmosphere, which regenerates the pellets' absorbency and allows them to be reused.

Benefits

Diesel-reforming technology is clean and efficient. Converting high-sulfur diesel into a clean energy source avoids the air emission concerns associated with burning it in conventional combustion systems that have nitrous oxide emissions. And the energy conversion rate is much higher with an integrated reformer/fuel cell system than with standard gas turbines.

The technology has implications for military security as well as humanitarian aid. Reformer/fuel cell systems run more quietly and at lower temperatures than do gas turbine engines, so naval ships equipped with this new technology would be more likely to display smaller infrared and acoustic signatures, making them more difficult to see. Developing countries, remote U.S. communities such as in Alaska, and war-torn areas are often deprived of access to power grids. Diesel reforming and fuel cell systems could provide efficient and environmentally sustainable alternatives to diesel generators. Finally, critical infrastructure facilities such as hospitals and shelters could use the new technology for backup emergency power.

This diesel reforming process, could lead to technology that delivers innovative energy solutions -- from clean electric power on Navy ships to stand alone power systems for remote areas such as rural Alaska.

The Integrated Fuel Processor was constructed inside the INL Engineering Demonstration Building (below).